Hydrogen Basics

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HYDROGEN HISTORY:

- Town gas was commonly used in the late 1800s and early 1900s.

- Piped throughout towns for lighting and cooking.

- Town gas was approximately:
  - 50% Hydrogen,
  - 45% CO_2, CH_4
  - 5% CO

- Town gas is still used in parts of Asia today.

HYDROGEN HISTORY: The Hindenburg

•In the 1990's NASA scientist, Dr. Addison Bain, conducted an in-depth study of the events surrounding the Hindenburg Disaster. He concluded:

- •There had been an electrical storm in the area shortly before the ship attempted to dock. The mooring lines were wet and grounded the ship when they were thrown down. The event initiated a corona effect on the ship's surface near the tail.
- •The cotton skin had been painted with aluminized cellulose acetate butyrate dopant: rocket fuel!
- •There was no hydrogen explosion.

HYDROGEN HISTORY: The Hindenburg (cont'd)

•The 35% of passengers who died were killed by jumping or caught in burning diesel fuel, canopy or other debris.

•The film shows flames that are typical of a forest fire.

•The 65% who survived rode the the flaming dirigible to the ground while the clear hydrogen flames swirled above them.

•The nose of the dirigible, filled with hydrogen, slowly lowered the ship to the ground – the hydrogen was being consumed in the fire. It didn't explode.

HYDROGEN TODAY:

•Over 500 miles of hydrogen piping exist in the US today.

•9 Million tons of hydrogen are produced in the US. 50 Million tons are produced globally.

•Most hydrogen is produced by steam reformation of natural gas:

- •80% steam reformation,
- •15% chemical processing by-product
- •5% electrolysis

•Air Products has never had a hydrogen pipeline fire in 35 years.

HYDROGEN BASICS:

•Hydrogen is colorless, odorless, tasteless, non-toxic, environmentally friendly.
Nobody has ever had to clean up a hydrogen spill!

•Hydrogen is an energy carrier like electricity or gasoline NOT an energy source like oil, coal, wind or sunlight.

•H2 is not an energy source because it's almost never found by itself.

•Hydrogen makes up about 75% of the known universe. However, nearly all of it is bound up in water and hydrocarbons.

•H2 used as a fuel directly yields only water.

HYDROGEN BASICS:

•Hydrogen is the lightest element and molecule.

•H2 is 8 times lighter than natural gas. Per unit of energy contained, H2 weighs 64% less than gasoline or 61% less than natural gas.

•1 kg of hydrogen has about the same energy as 1 gallon of gasoline which weighs 2.8 kgs. Gasoline has 22 times the explosive power per unit of volume than gaseous hydrogen.

•Hydrogen is 14.4 times lighter than air. Natural gas is only 1.7 times lighter than air.

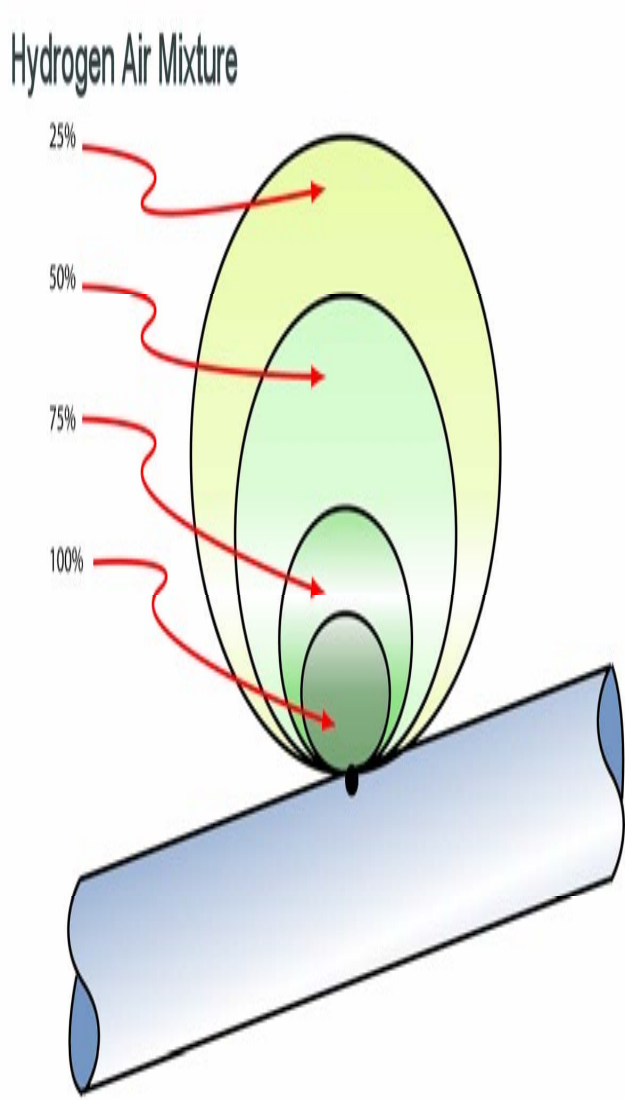
•Hydrogen is four time more diffusive than natural gas and 11 times more diffusive than gasoline fumes.

Properties of Hydrogen

Property	Hydrogen	Methane	Propane	Gasoline
Lower Flammability Limit	4%	5.3%	1.7%	1.0%
Lower Detonation Limit	18.3%	6.3%	3.1%	1.1%
Upper Detonation Limit	59%	13.5%	9.2%	3.3%
Upper Flammability Limit	75%	17%	10.9%	6.0%
Auto Ignition Temperature	585 C	537 C	487 C	228-471 C
Minimum Ignition Energy	0.017 mJ	0.274 mJ	0.240 mJ	0.240 mJ

Properties of Hydrogen
A look at flammability range:

Property	Hydrogen	Methane	Propane	Gasoline
Lower Flammability Limit	4%	5.3%	1.7%	1.0%
Lower Detonation Limit	18.3%	6.3%	3.1%	1.1%
Upper Detonation Limit	59%	13.5%	9.2%	3.3%
Upper Flammability Limit	75%	17%	10.9%	6.0%
Auto Ignition Temperature	585 C	537 C	450 C	228-471 C
Minimum Ignition Energy	0.017 mJ	0.274 mJ	0.240 mJ	0.240 mJ



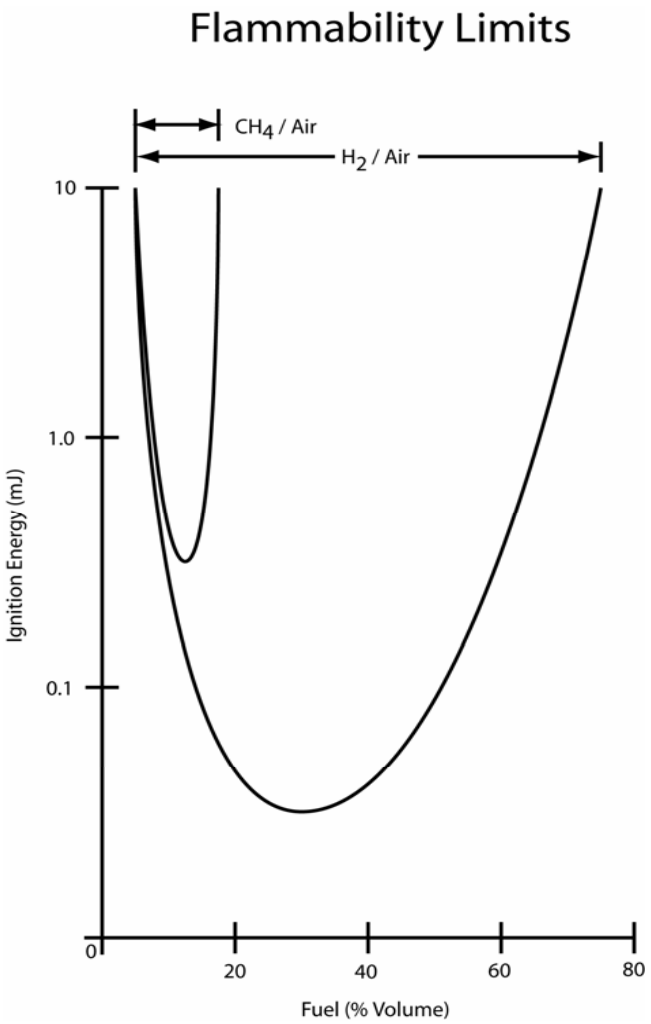
Upper Flammability Limit is of less practical consequence since the radius of concern is defined by the LFL.

Tendency to ignite before large accumulation of energy associated with stochiometric mixtures.

4 times higher concentration than gasoline required to get ignition yet it disperses 11 times faster. It is only half as likely as gasoline to ignite in open air.

Properties of Hydrogen
A look at ignition energy:

Property	Hydrogen	Methane	Propane	Gasoline
Lower Flammability Limit	4%	5.3	1.7	1.0
Lower Detonation Limit	18.3	6.3	3.1	1.1
Upper Detonation Limit	59	13.5	9.2	3.3
Upper Flammability Limit	75	17	10.9	6.0
Auto Ignition Temperature	585 C	537 C	450 C	228-471 C
Minimum Ignition Energy	0.017 mJ	0.274 mJ	0.240 mJ	0.240 mJ



Lowest ignition energy at stochiometric point.

At 4-10% concentrations, ignition energy of H2 is comparable to natural gas.

Tendency to ignite and burn before large energy accumulation occurs.

Typical static shock is 10 mJ. It could ignite methane, propane, gasoline and hydrogen.

HYDROGEN BASICS:

•It is unlikely that odorants will ever be used with hydrogen as a fuel. (The Hindenburg used garlic as an odorant.)

•Ventilation is very important. Hydrogen will rise buoyantly at up to 20 m/s and diffuses rapidly to a safe concentration.

•In a sealed room, hydrogen will rise initially and then diffuse to a uniform concentration.

•High energy/unit mass, but very low energy density. About 1/3rd of N's energy density and 1/8th of gasoline's energy density.

•Hydrogen has a higher auto-ignition temperature than gasoline.

HYDROGEN BASICS:

•Hydrogen burns with a very hot flame which is bluish/nearly invisible.

•Burning hydrogen emits 1/10th the radiant energy of a hydrocarbon flame.

•In the event of a hydrogen fire, the source should be shut off.

•If the source cannot be isolated, DO NOT EXTINGUISH THE HYDROGEN FLAME. Let it burn. Prevent flames from spreading to other combustibles.

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